Further Studies on the Effect of Heat Processing on Tomato Juice Color[a]

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An equation for calculating color loss, derived from a previous study (1), is tested against selected variables comparable to conditions encountered in commercial processing. The equation is shown to be valid under such conditions; namely, differences in heating media, container sizes, and color of raw stock.

Work carried out during the 1952 tomato season showed that the effect of heat application on the color loss of tomato juice proceeded in accordance with the equation: color loss $= \frac{Ts}{525} \frac{(RT-120)}{(40)}$, where color loss is in terms of U. S. grade points, Ts refers to temperature summation in terms of ° F. above 140, multiplied by seconds, and RT is the retort temperature *(1)*.

This work was done with specially devised equipment, and several questions remained unanswered as to the applicability of the equation to commercial processing conditions. Consequently, studies were undertaken during the 1953 season to determine whether this equation remains valid under the following conditions:

A. Use of heating media other than oil baths such as steam retorts.

B. Use of containers of different sizes and shapes.

C. Use of raw stock differing in color quality.

D. Combinations of different heating temperatures.

Effects of heating temperatures and heating times on the validity of the equation were also re-examined.

EXPERIMENTAL

Materials and methods used during the 1953 season were similar to those used during 1952, for determining the effect of combinations of different heating temperatures (Table 5). For the other experiments, where different can sizes and steam heating were involved, Ecklund thermocouples and steam retorts were used in addition to the equipment described previously *(1)*.

Studies on the Effect on Color of Selected Variables

Media and container. The effect of different heating media, container sizes, and times and temperatures of heat application was studied in a factorial experiment consisting of 60 samples for which heating cooling curves were obtained. The color of each sample was obtained before the heat treatment was applied and again after the heat treatment was concluded. Also, the temperature summation was determined from the heating cooling curve, and color loss was determined by the use of the chart in Figure 1. Data in Table 1 represent the difference between the calculated values and the actual color loss obtained for these samples when the U. S. grade equivalent of the processed samples was subtracted from the grade of the raw juice.

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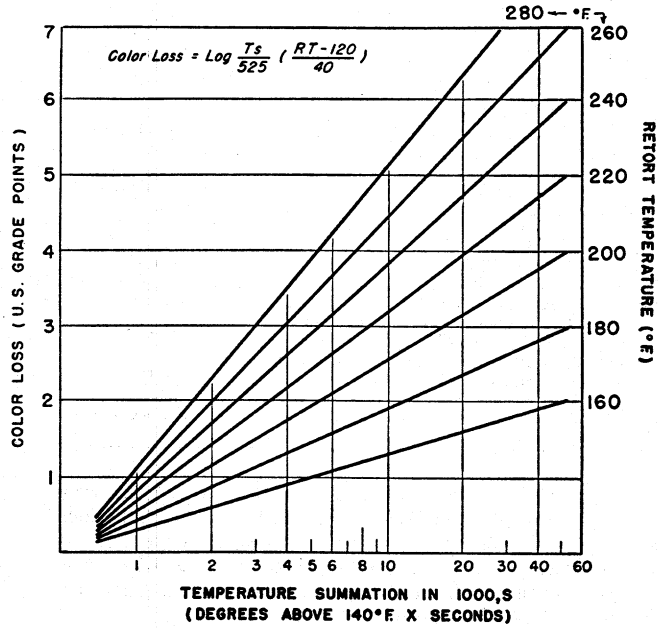

Figure 1. Nomograph for predicting color loss in tomato juice from temperature summations at different retort temperatures.

These results are summarized in Table 2, where it may be noted that in general the calculated results were approximately one-third of one point higher than the results actually obtained. This slight difference may indicate the presence of a slight constant error. The lack of any significant difference among the various treatments may be taken to indicate that the calculated results apply satisfactorily for different heating media, container sizes, and temperatures of heating media. Although the heating time factor was not quite statistically significant, there appeared to be a tendency for those samples which were processed for longer periods of time to have a somewhat higher calculated color loss than that which actually occurred. However, since these long durations of processing are not ordinarily met in commercial practice, it appears safe to state that the equation is valid for all 4 factors of temperature and time in the media, nature of media, and container size.

Raw stock color. Loss of color from tomato juice is obviously a measure of loss of the red color. If raw stock consisting

TABLE 1

Calculated values (+ or —) of color loss of tomato juice during processing as compared to the actual color loss

Can size	Duration of heating [1]	Retort temp. 230° F.		Retort temp. 240° F.	
		Oil bath	Steam retort	Oil bath	Steam retort
4 oz.	1	+0.1	—0.1	+0.1	+0.5
	2	+0.3	+0.1	—0.3	+0.7
	3	+1.2	—0.6	+0.2	+0.5
	4	+0.8	0.0	+0.2	+0.8
	5	+0.6	+0.9	+0.4	+0.2

[1] Duration of heating. Juice removed from heating media when: 1—Temperature of juice reached within 20° F. of the temperature of the media, 2—temperature of juice reached within 10° F. of the temperature of the media, 3—temperature of juice reached the temperature of the media, 4-10 minutes after temperature of juice reached temperature of media, and 5-20 minutes after temperature of juice reached temperature of media.

TABLE 2

Summary of the effects of various factors on calculated color loss as plus or minus actual color loss in terms of grade points.

Type of Heating Medium:	
Oil bath	+0.343
Steam retort	+0.293
L. S. D.	Not significant
F Value	0.50
Container Size:	
4 ounce can	+0.330
No. 1 picnic can	+0.295
No. 2 can	+0.320
L. S. D.	Not significant
F Value	0.49
Temperature of Heating Medium (RT):	
230° F.	+0.303
240° F.	+0.333
L. S. D.	Not significant
F Value	0.17
Time in heating medium:	
Up to 20° F. below RT	−0.025
Up to 10° F. below RT	+0.210
Up to temperature equal to RT	+0.375
5 minutes longer than time required to reach temperature equal to RT	+0.575
10 minutes longer than time required to reach temperature equal to RT	+0.433
L. S. D.	Not significant
F Value	2.44

of immature green tomatoes or yellow tomatoes were used, very little color loss would occur as a result of heat treatment, since there would be nothing present in the raw stock to be lost. It became of interest, therefore, to establish the point at which this color loss resulting from the application of heat is retarded because of the lack of color in the raw product.

For this purpose, 4 lots of raw tomatoes were selected carefully, with the purpose of providing material that would grade *high fancy, low fancy, standard,* and *substandard* after processing. Half of each of these 4 lots was heat processed so that, by calculation, the processed product would be 2 grade points lower than the original raw juice. The remaining material was heat processed for a longer period of time so that the calculated grade would be 3 grade points lower than the original raw juice. These 8 treatments were replicated 4 times. The results (Table 3) indicate that for the commercial range calculated color losses agree quite well with the actual losses found. As the sub-

TABLE 3

Effect of original raw juice color on color loss of tomato juice during heat processing (Values equivalent to grade score points)

Raw juice	Processed to cause calculated color loss of:			
	2.0		3.0	
	Score	Loss	Score	Loss
Top Fancy				
32.4	30.2	2.2	29.2	3.2
32.1	30.1	2.0	29.0	3.1
32.0	30.0	2.0	29.0	3.0
32.3	30.1	2.2	29.0	3.3
Low Fancy				
29.3	27.0	2.3	26.0	3.3
28.7	26.9	1.8	26.0	2.7
28.9	27.0	1.9	25.7	3.2
29.0	26.7	2.3	25.7	3.3
Standard				
25.9	24.0	1.9	23.1	2.8
25.8	24.0	1.8	23.4	2.4
25.9	23.8	2.1	23.2	2.7
26.0	24.0	2.0	23.2	2.8
Sub-Standard				
21.8	20.8	1.0	19.7	2.1
21.7	20.7	1.0	20.1	1.6
21.6	20.6	1.0	19.9	1.7
21.8	21.0	0.8	19.9	1.9

standard range of color is approached, however, the calculated color losses became greater than those actually found. These results are summarized in Table 4.

Multiple heating temperatures. It is common practice to preheat tomato juice to temperatures below 210° F. before sterilizing at higher temperatures. In order to simulate such conditions, samples of raw tomato juice were preheated in a 210° F. water bath

TABLE 4

Summary of the effect of raw juice color on calculated color loss as plus or minus actual color loss in terms of grade points

Color of raw juice	Difference of calculated color loss from actual
Top fancy (29)	+0.125
Low fancy (26)	+0.100
Standard (23)	−0.375
Substandard (19)	−1.111
L. S. D.	0.192
F Value	73.30

until juice temperatures reached 180, 190, or 200° F. The heat exchange cell was then placed in a cooling bath until the juice temperature dropped to 105° F., whereupon the cell was placed in an oil bath where the heat was maintained at 245, 255, 265, 275, and 285° F.; the cell was removed from the oil bath when juice temperature reached 240, 250, 260, 270, or 280° F. and cooled. In this way, a total of 45 double heating-cooling curves were obtained. Color was determined on the fresh juice, and again on each sample after heating and cooling in the water and oil baths.

The results (Table 5) show the temperature summations for each sample in the water bath and oil bath separately, together with the calculated color loss values as compared to color loss values obtained by subtracting the actual color values obtained on the heated samples from the color values of the original raw tomato juice. It is obvious from these data that the assumption made previously (A) is correct; namely, that every successive heat treatment is additive in effect and should not be calculated as the beginning of a new computation. This is necessary since color loss is a logarithmic function of temperature summation, and every increment in heating time results in a proportionately smaller increment in color loss.

The method of calculating this color loss resulting from heating at two different temperatures is demonstrated in Figure 2, as follows. For the temperature summation for the preheat treatment of 3.8 (thousand), a color loss of 1.9 grade points is indicated by reference to the figure, since the retort temperature

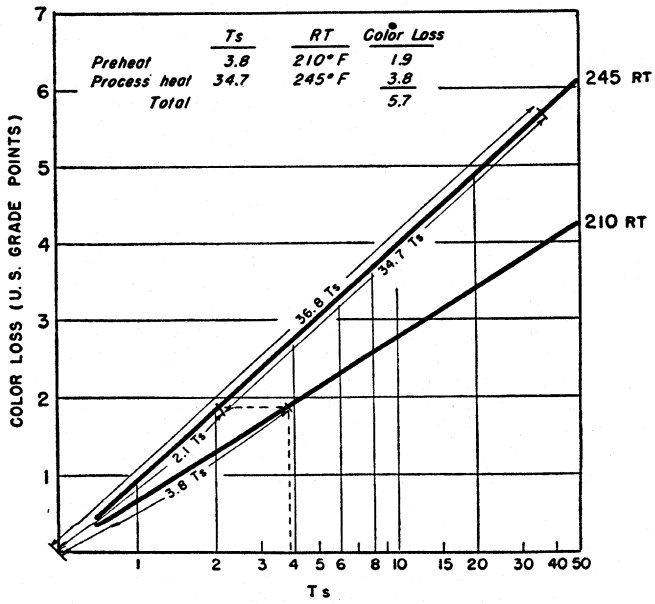

Figure 2. Relation of temperature summations to color loss showing the calculation of color loss when combinations of different retort temperature are employed in processing.

TABLE 5

Effect of preheating tomato juice on final color loss as found and as calculated (all temperatures as °F.)

1	2	3	4	5	6	7	8	9	10
Oil bath temperature	Juice temperature raised to:		T. S. water bath	Calculated [1] color loss	Corrected [2] color loss	T. S. oil bath	Total [3] T. S.	Calculated [4] total color loss	Actual [5] color loss
	In water bath	In oil bath							
245	180	240	3.8	1.9	2.1	34.7	36.8	5.7	5.9
	190	240	4.6	2.2	2.3	36.1	38.4	5.8	6.1
	200	240	10.2	2.9	4.1	34.6	38.7	5.8	6.5
255	180	240	2.9	1.7	1.8	22.5	24.3	5.5	5.4
		250	3.6	1.9	2.0	36.4	38.4	6.2	6.6
	190	240	6.6	2.4	3.0	24.7	27.7	5.7	6.6
		250	5.6	2.2	2.8	37.1	41.3	6.3	7.1
	200	240	9.6	2.9	4.0	23.7	27.7	5.7	6.1
		250	9.8	2.9	4.0	37.3	41.3	6.3	6.4
265	180	240	3.4	1.9	1.8	19.3	21.1	5.7	6.3
		250	3.7	2.0	1.9	26.8	28.7	6.2	6.9
		260	3.8	2.0	1.9	49.6	51.5	7.2	8.0
	190	240	5.0	2.3	2.4	17.8	20.2	5.6	5.2
		250	5.4	2.4	2.5	26.3	28.8	6.2	6.7
		260	7.2	2.6	2.8	74.7	77.5	5.7	8.0
	200	240	9.2	2.9	3.2	18.7	22.1	5.8	5.8
		250	10.5	3.0	3.6	26.4	30.0	6.3	6.3
		260	9.4	2.9	3.4	46.4	49.8	7.1	6.9
275	180	240	3.4	1.9	1.8	19.3	21.1	5.7	6.3
		250	3.8	2.0	1.8	20.0	21.8	6.2	5.5
		260	2.5	1.6	1.4	28.6	30.0	6.7	6.2
		270	4.0	2.0	1.8	46.8	48.6	7.6	6.8
	190	240	5.5	2.3	2.1	17.1	19.2	6.0	5.5
		250	7.2	2.6	2.5	19.4	21.9	6.2	5.6
		260	5.7	2.4	2.2	26.9	29.1	6.7	6.6
		270	6.2	2.5	2.4..	42.7	45.1	7.5	7.4
	200	240	10.2	3.0	3.2	15.2	18.4	5.9	5.2
		250	13.7	3.3	3.8	18.2	22.0	6.2	6.2
		260	9.9	2.9	3.0	29.2	32.4	6.9	7.3
		270	11.2	3.0	3.2	45.1	48.3	7.6	7.7
285	180	240	2.7	1.6	1.4	11.1	12.5	5.6	5.1
		250	2.8	1.7	1.4	13.9	15.3	6.0	5.4
		260	3.8	2.0	1.8	18.2	20.0	6.5	5.9
		270	2.4	1.5	1.3	24.9	26.2	7.0	7.1
		280	3.1	1.8	1.5	34.5	36.0	7.7	7.7
	190	240	5.2	2.3	2.0	14.8	16.8	6.1	5.3
		250	5.2	2.3	2.0	17.4	19.5	6.4	6.1
		260	4.8	2.2	1.9	21.1	23.0	6.8	7.2
		270	2.4	1.5	2.0	26.6	28.6	7.2	7.8
		280	4.8	2.2	1.9	51.3	53.2	8.3	8.4
	200	240	12.8	3.2	3.2	13.2	16.4	6.0	4.6
		250	12.1	3.1	3.0	16.3	19.3	6.4	6.1
		260	9.9	2.9	2.7	22.7	25.4	6.9	7.1
		270	8.3	2.8	2.6	30.2	32.8	7.5	7.4
		280	8.8	2.8	2.7	54.1	56.8	8.5	8.2

Legend:

[1] Values in terms of U. S. grade points calculated from nomograph (Figure 2) at 210° F.

[2] Calculated as follows: Calculated color loss at 210° F. in water bath (Column 5) converted to temperature summations at 245° as indicated in Figure 2.

[3] Summation, columns 6 and 7.

[4] Calculated from nomograph (Figure 2) at 245° F.

[5] As determined by Hunter C-D meter.

(RT) for this preheating treatment is 210° F. At the process retort temperature of 245° F., an equivalent color loss of 1.9 grade points would be obtained with only 2.1 (x 10^3) temperature summations (Ts). Hence, this value of 2.1 (x 10^3) Ts is added to the 34.7 (x 10^3) Ts obtained during the process heating at 245° F. for a total of 36.8 (x 10^3) Ts which at an RT of 245° F., would indicate a total color loss of 5.7 grade points.

SUMMARY

Within the limits of good commercial practice, the equation:

$$\text{Color Loss} = \frac{Ts}{525}\,\frac{(RT-120)}{(40)}$$

and the nomograph derived from the equation, are valid for calculating color loss in tomato juice under variable conditions of types and temperatures of heating media, container size, and raw stock quality. Where more than one heat treatment is applied, each successive heat application is calculated as an additive effect, rather than the beginning of a new calculation.

LITERATURE CITED

1. Kramer, A., and El-Kattan, A. A. Effect of application of heat on tomato juice color. *Food Technol.*, 7, 400-4 (1953).